A GUIDE TO
PRACTICAL CHEMISTRY
FOR THE
CONJOINT BOARD

RICHARDS

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PRACTICAL CHEMISTRY.

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GUIDE TO THE EXAMINATION
IN
PRACTICAL CHEMISTRY
FOR
THE CONJOINT BOARD.

BY

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INTRODUCTION.

THE first part of this little book consists of a list of metals and acid radicals, together with their most important and satisfactory tests. This portion of the practical work should be carried out first of all, in order to make the student thoroughly familiar with the various reactions, etc. After he has practised the tests for each member of a group (*e.g.*, the Hydrochloric Acid Group, consisting of lead, silver, and mercurous salts), one of these should be given him as an 'unknown,' to be detected without the aid of the book. This will enable him to ascertain how far he remembers the tests for one group before passing to the next. When he has tried the reactions for every metal and acid radical, the student may pass to the detection of solutions and solids containing a base combined with an acid, constituting what are known as Simple Salts.

The following general hints should be carefully borne in mind when commencing the analysis of a simple salt :

1. Be quite sure, before trying any test, that your test-tubes are clean ; it is as well to rinse them out with distilled water before starting.

2. When examining a solution, do not take more than about an inch in the test-tube for each test.

3. When using a reagent, add first a few drops, notice any change, and then in each case add a larger quantity, to see if any further result takes place.

4. If the substance is a solid, do not at first take more than enough to just cover the bottom of the test-tube, boil this with about twenty times its bulk of water, and, if it does not dissolve, boil a similar amount with sufficient hydrochloric acid to fill the tube half an inch; again, if this does not effect solution, use nitric acid under the same conditions. Remember, however, in the latter case, that the excess of nitric acid should be almost entirely expelled by boiling before proceeding with the tests.

5. In trying the Flame Tests always add a little hydrochloric acid to a portion of the solution or solid before placing it on the platinum wire in the Bunsen flame.

The notes on 'Preparations,' given on page 38, should be carefully read through before commencing this part of the practical work.

A summary of the equations representing the reactions given in the book will be found on page 54.

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PRACTICAL CHEMISTRY.

SPECIAL TESTS FOR THE METALS.

Group A.

Metals precipitated as Chlorides on addition of Hydrochloric Acid.

Lead (Pb).

1. Hydrochloric acid, *white precipitate* ($PbCl_2$), except in weak solutions; soluble in boiling water, but unaffected by addition of ammonium hydrate (NH_4OH).
2. Hydric sulphide (H_2S) gives a *black precipitate* (PbS). This precipitate is sometimes red at first.
3. Potassium iodide (KI) gives a *yellow precipitate* (PbI_2), soluble in hot water containing a trace of nitric acid (HNO_3); reprecipitated, upon cooling the solution, in the form of *golden spangles*.
4. Potassium chromate (K_2CrO_4) gives a *yellow precipitate* ($PbCrO_4$), soluble in potassium hydrate (see Bismuth).
5. Sulphuric acid (H_2SO_4) gives a *white precipitate* ($PbSO_4$).

Silver (Ag).

1. Hydrochloric acid gives a *white precipitate* (AgCl), insoluble in boiling water, but dissolving on addition of ammonium hydrate.
2. Potassium hydrate, *grey-brown precipitate* (Ag_2O).
3. Hydric sulphide gives a *black precipitate* (Ag_2S).
4. Potassium iodide gives a *whitish-yellow precipitate* (AgI).
5. Potassium chromate gives a *crimson precipitate* (Ag_2CrO_4).

Mercury (as **Mercurous Salts**) (Hg′).

1. Hydrochloric acid, *white precipitate* (HgCl); turns *black* on addition of ammonium hydrate owing to formation of mercurous chloramide (NH_2Hg_2Cl).
2. Hydric sulphide gives a *black precipitate* (Hg_2S).
3. Potassium iodide gives a *finch-green precipitate* (Hg_2I_2).
4. Stannous chloride gives a so-called *magpie precipitate* (white changing to black), consisting first of HgCl, then Hg.
5. Boiled with hydrochloric acid and a strip of bright copper, the latter becomes coated with silvery deposit of mercury which volatilizes when heated in a dry tube.

GROUP B.

Metals precipitated as Sulphides by Hydric Sulphide in the presence of Hydrochloric Acid.

Mercury (as **Mercuric Salts**) (Hg″).

1. Hydric sulphide and hydrochloric acid, when the former is added carefully, produce a precipitate changing from *white* through *yellow and orange to black* (HgS).
2. Potassium iodide gives a *red precipitate* (HgI_2), soluble in excess of either solution.
3. Stannous chloride gives a *white precipitate*, changing to *grey-black*, as with mercurous salts.
4. Potassium hydrate gives a *yellow precipitate* (HgO).
5. See Mercurous Salts, No. 5.

Bismuth (Bi). (Strong solutions of $BiCl_3$ or $Bi3NO_3$ give *white precipitates* ($BiOCl$ or $BiONO_3$) with water.)

1. Hydric sulphide, *dark brown precipitate* (Bi_2S_3), insoluble in ammonium sulphide, but soluble in hot nitric acid.
2. Potassium hydrate, *white precipitate*, insoluble in excess ($Bi(OH)_3$); turns yellowish on boiling.
3. Potassium chromate, *deep yellow precipitate* ($Bi_2(CrO_4)_3$), insoluble in potassium hydrate (see Lead).
4. Potassium iodide, *brown precipitate* (BiI_3).

Copper (Cu).

1. Hydric sulphide, *black precipitate* (CuS), insoluble in ammonium sulphide.
2. Potassium hydrate, *blue precipitate*

($Cu(OH)_2$); becomes *black* (CuO) on boiling with excess of the alkali.

3. Ammonium hydrate, *greenish-blue precipitate*, soluble in excess to *deep blue coloration.*
4. Potassium ferrocyanide (K_4FeCy_6), *chocolate precipitate* (Cu_2FeCy_6).

Antimony (Sb). (Strong solutions of $SbCl_3$ give *white precipitate* ($SbOCl$) with water, soluble in tartaric acid.)

1. Hydric sulphide, *orange-red precipitate* (Sb_2S_3), soluble in ammonium sulphide after neutralizing with ammonia to prevent precipitation of sulphur. Soluble also in hot strong HCl.
2. Potassium hydrate, *white precipitate* (Sb_2O_3), soluble in excess.
3. Ammonium hydrate, *white precipitate*, insoluble in excess.
4. Boiled with hydrochloric acid and strip of bright copper, gives a *violet-black film;* the latter, dried and heated, is volatilized as oxide.

N.B.—In tartar emetic ($K(SbO)C_4H_4O_6$) tests No. 1 and No. 4 only succeed, but HCl alone, in this case, gives *white precipitate*, soluble in excess.

Arsenic (As) (as **Arsenious Acid** or an **Arsenite**).

1. Hydrochloric acid and hydric sulphide, a *yellow precipitate* (As_2S_3), soluble in ammonium hydrate and in ammonium sulphide.

   N.B. — Hydric sulphide alone gives *yellow coloration.*

*2. Silver nitrate and a drop of ammonium hydrate, *yellow precipitate* (Ag_3AsO_3), soluble in excess of the ammonia, and also in nitric acid.

*3. Copper sulphate and a drop of ammonium hydrate, *Scheele's green* ($CuHAsO_3$), soluble in excess of ammonium hydrate to a deep blue solution.

4. Boiled with hydrochloric acid and strip of copper-foil, a *grey deposit* (Cu_3As_2) appears on the copper. The latter, dried and heated in a dry tube, yields a sublimate of arsenious oxide (As_4O_6), consisting of octahedral crystals (Reinsch's Test).

Arsenic (As) (as **Arsenic Acid** or an **Arsenate**).

1. Hydrochloric acid and hydric sulphide, usually no result until boiled down and second addition of hydric sulphide, then *yellow precipitate* ($As_2S_3 + 2S$).

*2. Silver nitrate and a drop of ammonium hydrate, *red-brown precipitate* (Ag_3AsO_4), soluble in excess of the ammonia and in nitric acid.

*3. Copper sulphate and a drop of ammonium hydrate, *greenish-blue* ($CuHAsO_4$), soluble in excess of the ammonia to a deep blue coloration.

4. Ammonium nitro-molybdate warmed, *yellow precipitate.*

5. Reinsch's test, as given in No. 4 for arsenious acid.

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* In tests 2 and 3 the addition of ammonium hydrate is only necessary when dealing with arsenious or arsenic acids.

GROUP C.

Metals precipitated by Ammonium Hydrate and Ammonium Sulphide.

Aluminium (Al).

1. Ammonium hydrate, *white gelatinous precipitate* ($Al(OH)_3$), insoluble in excess or in ammonium chloride.
2. Potassium hydrate, *white gelatinous precipitate* of the hydrate, soluble in excess as potassium aluminate ($K_2O.Al_2O_3.3H_2O$).
3. Sodium phosphate (Na_2HPO_4), *white precipitate* ($AlPO_4$), insoluble in acetic acid.
4. Heated with dry sodium carbonate on charcoal, moistened with cobalt nitrate ($Co(NO_3)_2$), and again heated, gives a *blue mass*, known as Thenard's blue.

Iron (as **Ferric Salt**) (Fe''').

1. Ammonium hydrate, *red precipitate* ($Fe(OH)_3$), insoluble in excess.
2. Ammonium sulphide, *black precipitate* (FeS), by reduction.
3. Potassium ferrocyanide, *Prussian blue precipitate* ($Fe_4(FeCy_6)_3$).
4. Potassium sulphocyanide, *blood-red coloration*, unchanged by hydrochloric acid.
5. Potassium ferricyanide, *olive coloration*.

Iron (as **Ferrous Salt**) (Fe'').

1. Ammonium hydrate, *greenish-white precipitate* ($Fe(OH)_2$), rapidly darkening from oxidation until it becomes brown ($Fe(OH)_3$).
2. Ammonium sulphide, *black precipitate* (FeS).
3. Potassium ferrocyanide, *pale blue precipitate* ($K_2Fe_2Cy_6$).

4. Potassium ferricyanide (K_3FeCy_6), *dark blue precipitate* ($Fe_3(FeCy_6)_2$).
5. Potassium sulphocyanide, *no colour* unless traces of ferric salts are present.

Zinc (Zn).

1. Ammonium hydrate, *white precipitate* ($Zn(OH)_2$), soluble in excess; then, on addition of
2. Ammonium sulphide, a *white precipitate* (ZnS), which appears yellow from the colour of the reagent if added in excess.
3. Potassium ferrocyanide, a *white gelatinous precipitate* (Zn_2FeCy_6).
4. Potassium ferricyanide, a *yellow precipitate* ($Zn_3(FeCy_6)_2$).
5. Heated on charcoal with dry sodium carbonate, moistened with cobalt nitrate, and again heated, gives a *green mass.*

GROUP D.

Metals precipitated as Carbonates on addition of Ammonium Hydrate, Ammonium Chloride, and Ammonium Carbonate.

Barium (Ba).

1. Ammonium carbonate, *white precipitate* ($BaCO_3$).
2. Potassium chromate, *yellow precipitate* ($BaCrO_4$), insoluble in acetic acid.
3. Sulphuric acid, *white precipitate* ($BaSO_4$), insoluble in hydrochloric acid.
4. Solution with hydrochloric acid on platinum wire gives *yellowish-green coloration* to Bunsen flame.

5. Calcium sulphate, *white precipitate* ($BaSO_4$).
6. Ammonium oxalate, *white precipitate* (BaC_2O_4).

Calcium (Ca).

1. Ammonium carbonate, *white precipitate* ($CaCO_3$).
2. Potassium chromate, *no precipitate.*
3. Sulphuric acid, *no precipitate.*
4. Ammonium oxalate, *white precipitate* (CaC_2O_4), insoluble in acetic acid.
5. Flame test, *red* (see No. 4 test for Barium).

Metal precipitated by Sodium Phosphate in presence of Ammonium Chloride and Ammonium Hydrate.

Magnesium (Mg).

1. Ammonium chloride + ammonium hydrate + sodium phosphate, *white crystalline precipitate* ($MgNH_4PO_4$).
2. Sodium phosphate, *white precipitate* ($Mg_3P_2O_8$).
3. Ammonium hydrate, *white precipitate* ($Mg(OH)_2$), increases on warming the solution.

   N.B.—This precipitate may not be obtained if free acid is present.
4. Sodium bicarbonate, *no precipitate* until the solution is boiled, then *white precipitate* ($MgCO_3$).
5. Heated with dry sodium carbonate on charcoal by blow-pipe flame, moistened with cobalt nitrate, and again heated, gives *pink mass.*

GROUP E.

Potassium (K).

1. Sodium carbonate, *no reaction* even when boiled (compare Ammonium).
2. Flame test, after moistening with hydrochloric acid, *violet colour*, which appears *red* when viewed through cobalt glass.
3. Concentrated solutions give with strong solutions of tartaric acid ($H_2C_4H_4O_6$) a *white crystalline precipitate* ($KHC_4H_4O_6$), increased by the addition of alcohol and shaking, or by rubbing the sides of the tube with a glass rod.
4. Concentrated solutions give, with strong solutions of platinum chloride ($PtCl_4$), a *yellow crystalline precipitate* ($2KCl.PtCl_4$), insoluble in alcohol—distinction from sodium.

Ammonium (NH_4).

1. Sodium carbonate, *no precipitate*, but on warming gives off ammonia (NH_3), recognised by smell, and by turning red litmus-paper blue if the latter is held in the gas.
2. Nessler's reagent ($HgI_2 + KI + KOH$) gives a *brown-red precipitate*.

3 and 4. Similar reactions to Nos. 3 and 4 of Potassium.

Sodium (Na).

1. Sodium carbonate, *no reaction*.
2. Platinum chloride, *no precipitate*.
3. Tartaric acid, *no precipitate*.

4. Flame test, *intense yellow colour*, invisible through cobalt glass (see No. 2 test for Potassium).
5. Like most metallic salts, sodium salts leave a white residue after evaporating to dryness and strongly heating.

TESTS FOR ACIDS.

Group A.

Acids or Acid-Radicals precipitated by Soluble Barium Salts.

Sulphates (Salts of Sulphuric Acid, H_2SO_4).

1. Barium chloride, *white precipitate* ($BaSO_4$), insoluble in hydrochloric acid.
2. Lead acetate, *white precipitate* ($PbSO_4$).
3. The barium sulphate obtained in No. 1 can be filtered off and heated strongly on charcoal, being thus converted into barium sulphide. This, placed on a piece of silver and moistened with HCl, gives a *black stain* (Ag_2S).
4. If the original solution is free sulphuric acid, a streak made on paper with a glass rod dipped in the liquid will, on drying, *char black.*

Carbonates (Salts of the hypothetical acid, H_2CO_3).

1. Barium chloride, *white precipitate* ($BaCO_3$), disappears with effervescence on addition of hydrochloric acid.
2. The gas obtained by last experiment, if passed into lime-water ($Ca(OH)_2$), will turn the latter *milky* from formation of $CaCO_3$.

3. Silver nitrate, *white precipitate* ($AgCO_3$).
4. Ferric chloride, *red precipitate* ($Fe(OH)_3$).
5. Solutions of normal carbonates of the alkalies are *strongly alkaline.*

Phosphates (Salts of Phosphoric Acid, H_3PO_4).

1. Barium chloride, *white precipitate* ($Ba_3P_2O_8$), soluble without effervescence in hydrochloric acid.
2. Calcium chloride, *white precipitate* ($Ca_3P_2O_8$), soluble in acetic acid.
3. Warmed with ammonium nitro-molybdate, gives a *yellow precipitate.*
4. A clear solution containing magnesium sulphate + ammonium chloride + ammonia added to the solution, gives a *white crystalline precipitate* ($MgNH_4PO_4$).
5. Silver nitrate, a *yellow precipitate* (Ag_3PO_4).

Oxalates (Salts of Oxalic Acid, $H_2C_2O_4$).

1. Barium chloride, *white precipitate* (BaC_2O_4), soluble without effervescence in hydrochloric acid.
2. Calcium chloride, *white precipitate* (CaC_2O_4), insoluble in acetic acid (compare Phosphates). The precipitate dissolves in HCl, and is immediately reprecipitated by ammonium hydrate.
3. A solid oxalate, heated with strong sulphuric acid, *does not char*, but evolves carbonic oxide gas, which *burns with a blue flame* when ignited at the mouth of the test-tube.
4. Silver nitrate, a *white precipitate* ($Ag_2C_2O_4$).

Tartrates (Salts of Tartaric Acid, $H_2C_4H_4O_6$).

1. Barium chloride, *white precipitate* ($BaC_4H_4O_6$), soluble without effervescence in hydrochloric acid.
2. Calcium chloride, *white precipitate*, soluble in hydrochloric acid, not immediately re-precipitated by ammonium hydrate.
3. If a solid tartrate be heated, *it chars*, and gives off an *odour of burnt sugar.*
4. A solid tartrate, or a concentrated solution, *chars strongly* when warmed with sulphuric acid, and gives off a mixture of sulphur dioxide, carbon dioxide, and carbonic oxide (compare Oxalates).
5. Silver nitrate + sodium hydrate + sufficient ammonium hydrate to just dissolve the precipitated Ag_2O, will, on warming, produce a *silver mirror* on the sides of the test-tube.

GROUP B.

Acid Radicals not precipitated by Soluble Barium Salts, but precipitated by Silver Nitrate.

Chlorides (Salts of Hydrochloric Acid, HCl).

1. Silver nitrate, *white precipitate* (AgCl), insoluble in nitric acid, but readily so in ammonium hydrate.

*2. Shaken with chlorine-water and a little carbon disulphide, the latter remains *uncoloured*.

3. Heated with manganese dioxide and strong sulphuric acid, yields *yellowish-green gas* (chlorine), recognised by smell and bleaching action on moist litmus-paper.

4. Lead acetate, *white precipitate* ($PbCl_2$).

Bromides (Salts of Hydrobromic Acid, HBr).

1. Silver nitrate, *yellowish-white precipitate* (AgBr), insoluble in nitric acid, but gradually soluble in ammonium hydrate.

*2. Shaken with chlorine-water and carbon disulphide, the latter turns *deep orange colour* from solution of free bromine.

3. Heated with manganese dioxide and strong sulphuric acid, evolves *brown fumes* (bromine)—notice the smell.

4. Lead acetate, *white precipitate* ($PbBr_2$).

Iodides (Salts of Hydriodic Acid, HI).

1. Silver nitrate, *yellowish-white precipitate* (AgI), insoluble in nitric acid, and also in ammonium hydrate.

*2. Shaken with chlorine-water and carbon disulphide, the latter turns *deep violet colour*.

3. Heated with manganese dioxide and strong sulphuric acid, evolves *violet fumes* (iodine) —notice the smell.

4. Lead acetate, *yellow precipitate* (PbI_2), soluble in boiling water, reprecipitated as spangles on cooling.

5. Chlorine-water in small amount and starch paste give *violet colour*.

Cyanides (Salts of Hydrocyanic Acid, HCN or HCy).

1. Silver nitrate, *white precipitate* (AgCy),

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* Chloroform will do in place of carbon disulphide in these tests.

soluble in excess of the original solution, forming, when that is KCy, a double cyanide (AgCy.KCy).

2. Boiled with potash and ferrous sulphate, then ferric chloride and hydrochloric acid added, gives *Prussian blue* ($Fe_4(FeCy_6)_3$).
3. Evaporated with ammonium sulphide, then hydrochloric acid and ferric chloride added, gives *blood-red coloration* ($Fe(CyS)_3$).

N.B.—The soluble cyanides are usually alkaline in reaction, and contain more or less carbonate, which causes barium chloride to give a precipitate, and is often a source of error to the student. The odour of cyanide is, however, characteristic enough to prevent the solution being returned as a carbonate.

Sulphides (Salts of Hydric Sulphide, H_2S).

1. Silver nitrate, *black precipitate* (Ag_2S), insoluble in ammonium hydrate.
2. Lead acetate, *black precipitate* (PbS).
3. HCl *evolves hydric sulphide,* and frequently precipitates sulphur. The H_2S may be detected by *smell,* and by *browning action* on paper soaked in lead acetate solution.
4. Sodium nitroprusside ($Na_2FeNOCy_5$) gives a *violet colour.* (This reaction is not given by free H_2S.)

Hydrates (type, Caustic Potash, KOH).

1. Silver nitrate, *grey-brown precipitate* (Ag_2O), soluble in ammonium hydrate.

   N.B.—This test will therefore not be given by *ammonium* hydrate except in very strong silver solutions.

2. Lead acetate, *white precipitate* ($Pb(OH)_2$).
3. Copper sulphate, *blue precipitate* ($Cu(OH)_2$), blackens on boiling (CuO) if excess of the hydrate is present.
4. Ferric chloride, *red - brown precipitate* ($Fe(OH)_3$).

   N.B.—Caustic alkalies often contain carbonate.

Acid Radicals not precipitated by Silver Nitrate.

Nitrates (Salts of Nitric Acid, HNO_3).

1. Both barium and silver nitrates give *no precipitate.*
2. Warmed with strong sulphuric acid and a piece of copper foil, *brown fumes* are observed, and the liquid turns *blue.*
3. Mixed with excess of strong sulphuric acid and thoroughly cooled, then ferrous sulphate solution poured carefully on the surface, a *black ring* ($2FeSO_4NO$) is produced.

Acetates (Salts of Acetic Acid, $HC_2H_3O_2$).

1. Both barium and silver nitrates give *no precipitate.*
2. Warmed with strong sulphuric acid, gives off an *odour of vinegar.*
3. As in No. 2, but with previous addition of alcohol, gives an odour of *acetic ether* ($C_2H_5C_2H_3O_2$).
4. A *neutral* acetate gives a *dark red colour* with ferric chloride, which changes to a *red precipitate* upon boiling.

Neutral Organic Substances.

Urea ($CO(NH_2)_2$).

1. Boiled with strong potash, yields ammonia —notice the smell, and confirm with moist red litmus-paper held in the gas.
2. Strong solutions, with strong nitric acid, give a *crystalline precipitate* ($CO(NH_2)_2 \cdot HNO_3$).
3. Sodium hypobromite gives effervescence (nitrogen).
4. On evaporating to dryness and strongly heating, no charring occurs, but solid residue gradually volatilizes.
5. Mercuric nitrate gives a *white precipitate.*
6. Nitrous acid gives off CO_2, which renders lime-water milky.

Glucose ($C_6H_{12}O_6$).

1. Boiled with potash, turns *brown.*
2. Potash and copper sulphate give *deep blue colour*, which on boiling becomes *a red precipitate* (Cu_2O).
3. Strong sulphuric acid, on warming, chars the solution.
4. On evaporating to dryness and strongly heating, the solid residue chars and burns away.

Sucrose ($C_{12}H_{22}O_{11}$).

1. Not affected by boiling with potash (see Glucose).
2. Potash and copper sulphate give *deep blue colour*, but *no reduction* (see Glucose).
3. Boiled with dilute hydrochloric acid and neutralized, the solution will reduce potash and copper sulphate.
4. See No. 4, Glucose.

EXAMINATION OF A SIMPLE SALT GIVEN IN THE SOLID STATE.

Take a small portion of the original powder, about the size of a pea, in a test-tube, add 2 inches of water, shake, and boil for a couple of minutes. If a portion of the substance has dissolved, filter, and examine the filtrate as in the case of a simple solution ; of course, if the whole dissolves, no filtration is necessary. If the powder is quite insoluble in water, take a fresh portion of the same bulk, boil with about half an inch of strong hydrochloric acid, and, if a solution is obtained, dilute with five times its bulk of water, then test portions of this solution for base and acid. If insoluble in hydrochloric acid, a fresh portion should be boiled with about the same amount of strong nitric acid, and, when solution is obtained, the excess of acid removed by further boiling (as it interferes considerably with certain tests), five times its bulk of water added, and the liquid examined as before.

The student should notice carefully any gas evolved when hydrochloric acid is added, as the acid radical is frequently detected here. He should also bear in mind that when hydrochloric acid is added, the solution contains a *chloride*, and that when nitric acid is added a *nitrate* is produced, and also in the latter case oxidation may have taken place ; *e.g.*, a mercurous becomes a mercuric salt.

Carbonates insoluble in water may be detected by the addition of HCl, when strong effervescence takes place, the gas having no smell and giving an opalescence when poured into a test-tube containing an inch of lime-water ($Ca(OH)_2$).

Sulphides insoluble in water may be detected by the fact that they give off hydric sulphide (H_2S) when treated with HCl (may require heat). This gas can be recognised by its smell of rotten eggs, and also by its staining *brown-black* a piece of paper soaked in acetate of lead solution.

Metals may be detected frequently by their colour and appearance, and sometimes by evolving hydrogen when treated with HCl, or oxides of nitrogen with HNO_3.

Oxides, when treated with acid, *dissolve without evolution of gas* (unless traces of carbonate or other impurities are present). The liquid will give reactions for no acid except the one added to effect solution.

An insoluble body suspected of being a chloride, bromide, or iodide may be heated in the dry state with MnO_2 and strong H_2SO_4 to obtain the halogen. This may be confirmed by shaking the powder with chlorine-water and chloroform or carbon disulphide.

A LIST OF A FEW SALTS OFFERING SPECIAL DIFFICULTIES.

Arsenious oxide (As_4O_6), a white heavy powder; when boiled with water, part dissolves, but part floats persistently, and may give the student the idea that none has dissolved.

Mercurous chloride (HgCl), a yellowish-white heavy powder, turns black if NH_4OH is added to it. Dissolves sparingly in HCl, more readily in HNO_3, evolving brown fumes in the latter case, and undergoing oxidation, finally giving a solution of mercuric chloride and nitrate—

$$6HgCl + 8HNO_3 = 3Hg(NO_3)_2 + 3HgCl_2 + 2NO + 4H_2O.$$

Antimony oxide (Sb_2O_3).
Antimony oxychloride (SbOCl).
Bismuth chloride ($BiCl_3$).
Bismuth oxychloride (BiOCl).
Bismuth oxide (Bi_2O_3).
Bismuth oxynitrate ($BiONO_3$).

All these bodies require acid to dissolve them. The presence of nitric acid may be detected in the HCl solution, and the chlorine tested for by heating the original powder with $MnO_2 + H_2SO_4$, or by dissolving in nitric acid and adding silver nitrate.

Precipitated copper, a black powder with red tinge, insoluble in HCl (compare CuO), dissolves in HNO_3 with red fumes.

White precipitate powder ($HgClNH_2$), insoluble in water, dissolves in HCl, forming $HgCl_2$ and NH_4Cl. Where $HgCl_2$ is found in solution under these conditions, examine the original powder for ammonia by warming with NaOH, and for chlorine by heating with MnO_2 and H_2SO_4.

Antimony sulphide (Sb_2S_3), a slate-black powder, dissolves in warm HCl, evolving H_2S. Unless the solution so prepared is thoroughly boiled, the H_2S will not be completely expelled, and on addition of water an orange precipitate of Sb_2S_3 will form. When boiled thoroughly, water should be added, and also some more HCl to prevent any formation of a precipitate of oxychloride of antimony.

Mercuric sulphate ($HgSO_4$), a white crystalline heavy powder. On addition of water, turns yellow, owing to formation of a basic insoluble sulphate ($HgSO_4.2HgO$), whilst an acid soluble sulphate ($HgSO_4$ $2H_2SO_4$) dissolves. The whole powder dissolves readily in HCl.

Mercuric sulphide (HgS), a crimson or black powder, appears to be insoluble in HCl, but on boiling with the latter evolves a little H_2S, which can be detected by the blackening it produces on a piece of paper soaked in lead acetate solution. If a few drops of HNO_3 be now added to the strong HCl, and the mixture boiled, the sulphide becomes oxidized to sulphate, and dissolves. The sulphate can be detected in the solution by means of $Ba2NO_3$.

Mercuric iodide, a crimson powder, when boiled with HNO_3 gives violet fumes of iodine, proved by holding a piece of paper soaked in starch solution in the gas; the fumes turn it blue. The powder dissolves in $HCl + HNO_3$.

Mercuric cyanide, soluble in water, gives both H_2S and $SnCl_2$ reactions for mercury, but most tests do not succeed. The Prussian blue test proves the presence of cyanide, as also does the smell of HCN, which is evolved when the solid or solution is treated with HCl.

INSOLUBLE PHOSPHATES, OXALATES AND TARTRATES.

These bodies dissolve in hydrochloric acid, but on addition of ammonium hydrate give a white precipitate (consisting of the original salt), which may be mistaken for aluminium hydrate. Consequently, when a white precipitate has been obtained in Group C (metals), it is as well to test the original substance for phosphate, oxalate, and tartrate as follows, and, if a negative result is obtained, aluminium may be assumed to be present:

Phosphate.—Dissolve original substance in nitric acid, add ammonium molybdate and warm ; a yellow precipitate is formed.

Oxalate.—Heat the solid with strong sulphuric acid ; *no charring* takes place, but CO is evolved, and burns with a blue flame when ignited at the end of the test-tube.

Tartrate.—Heat the solid with strong sulphuric acid ; *charring* takes place, and SO_2, as well as CO, is evolved. The original solid also chars when ignited, and smells of burnt sugar.

If a phosphate, oxalate, or tartrate is found under these conditions, proceed as follows :—

(*a*) Heat the original powder with anhydrous sodium carbonate, extract the mass with water, and filter. The residue will be the carbonate of the metal, and this can be dissolved in HCl, and the base detected in the ordinary way.

Or

(*b*) To the hydrochloric acid solution add ammonium hydrate until a precipitate forms, then acetic acid to dissolve this ; finally add sodium acetate and ferric chloride drop by drop until the liquid is distinctly red. The mixture should be then boiled, and filtered whilst boiling. This filtrate will give the reactions for the metal present, and will be free from phosphate, oxalate, or tartrate.

PRELIMINARY EXAMINATION OF A SIMPLE SALT.

I. Try the effect on litmus-paper—

(*a*) *Strongly acid.* See (II. *b*) below.
(*b*) *Strongly alkaline*, a hydrate, carbonate, phosphate, arsenite or arsenate of an alkali metal is probably present.

II. To original solution add Sodium Carbonate Solution :*

(*a*) **Precipitate** indicates *a salt of a heavy metal.* In this case proceed through Table of Metal Groups.

(*b*) **Effervescence** (but no precipitate) indicates *a free acid, an acid-salt of sodium, potassium, or ammonium,* or possibly *arsenious acid in hydrochloric acid.* Test with $HCl + H_3S$ for arsenic, and if no result, evaporate to dryness, test for sodium, potassium, or ammonium, and if no result proceed to Acid Table.

(*c*) **No precipitate and no effervescence** indicates a neutral *salt of sodium, potassium, or ammonium ;* or possibly an *arsenic* salt, *tartar emetic, glucose, sucrose, or urea.* Evaporate to dryness and strongly heat a very little of the solution ; notice any charring and smell of burnt sugar, which would indicate the presence of glucose, sucrose, tartar emetic, or an organic salt of sodium, potassium, or ammonium. Test with $HCl + H_2S$ for antimony or arsenic, and, if these are present or absent, proceed to sodium, potassium and ammonium, and thence follow the table.

If all metals are absent, test separately for glucose, sucrose and urea.

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* This does not apply to the hydrochloric or nitric acid solution of a substance insoluble in water.

SEPARATION TABLE.

N.B.—Add the reagent in every case to the *original solution*, unless the contrary is specially stated.

GROUP TESTS FOR METALS.

A. Hydrochloric acid gives a white precipitate, which, on addition of ammonium hydrate,

Dissolves	*Blackens*	*Remains unaffected.*
Silver.	**Mercurous.**	**Lead.**
KI gives whitish-yellow precipitate. K_2CrO_4 gives red precipitate.	KI gives yellow-green precipitate. $SnCl_2$ gives white precipitate changing to black.	KI gives bright yellow precipitate, soluble in boiling water. K_2CrO_4 gives yellow precipitate, soluble in NaOH.

If hydrochloric acid gives no precipitate, or one dissolving in excess of acid, pass to *Table B.*

B. Add to the solution containing the Hydrochloric Acid some **Hydric Sulphide** (H_2S), at first drop by drop, but finally excess, and warm,

Canary-yellow Precipitate.	*White,* changing *Yellow, Orange,* and finally *Black Precipitate.*	*Orange Precipitate.*	*Brown Precipitate.*	*Black Precipitate.* Add NaOH to original solution.	
				Blue Precipitate.	*White Precipitate.*
Arsenic (Arsen*ious* salts). Yellow precipitate, dissolves at once in NH_4OH. *N.B.*—Arsen*ic*-salts are only precipitated after long boiling and much H_2S.	**Mercuric.** KI, scarlet precipitate. $SnCl_2$, white to black precipitate.	**Antimony.** NH_4OH, white precipitate. Reinsch's test.	**Bismuth.** KI, brown precipitate. NaOH, white precipitate.	**Copper.** NH_4OH, dark blue coloration. K_4FeCy_6, chocolate precipitate.	**Lead.** KI, bright yellow precipitate, sol. in boiling water.

If $HCl + H_2S$ give no precipitate or an indefinite milky precipitate, pass to *Table C.*

C. Add to the original solution **Ammonium Chloride** and then **Ammonium Hydrate** in excess,

White Precipitate (insoluble in excess).	*Dirty-green Precipitate.*	*Red-brown Precipitate.*	*No Precipitate.* Add **Ammonium Sulphide** to same solution.	
			White Precipitate.	*No Precipitate.*
Aluminium. K_4FeCy_6, no precipitate. *N.B.* — See note on insoluble phosphates, etc., p. 28.	**Ferrous.** K_4FeCy_6, pale blue precipitate. K_3FeCy_6, dark blue precipitate (Turnbull's blue).	**Ferric.** K_4FeCy_6, dark blue (Prussian blue) precipitate. K_3FeCy_6, olive colour.	**Zinc.** K_4FeCy_6, white gelatinous precipitate. K_3FeCy_6, yellow precipitate.	Pass to *Table D.*

D. Add to the original solution **Ammonium Chloride + Ammonium Hydrate + Ammonium Carbonate,**

White Precipitate.		*No Precipitate.* Add to same solution **Sodium Phosphate.**	
		White Crystalline Precipitate.	*No Precipitate.*
Barium. $CaSO_4$ gives white precipitate. K_2CrO_4, yellow precipitate.	**Calcium.** $CaSO_4$ gives no precipitate. $(NH_4)_2C_2O_4$, white precipitate.	**Magnesium.** The original solid, or, in case of a solution, the residue obtained after evaporation, mixed with Na_2CO_3, ignited on charcoal, moistened with $Co2NO_3$, and again heated, gives *pink mass.*	Pass to *Table E.*

E. Warm original solution with **Sodium Hydrate** solution,

Smell of Ammonia. The gas turns red litmus blue.	*No Smell.* Evaporate a portion to dryness, heat to redness, white residue left,		
Ammonium. Nessler's reagent, red precipitate.	**Potassium.** Moisten with HCl and try *Flame test* with platinum wire, *violet.* The residue, obtained on evaporation, dissolved in a small amount of water, and shaken with a little strong tartaric acid solution, gives a *crystalline precipitate*, increased by the addition of a little alcohol.	**Sodium.** *Flame test* (see Potassium), *intense yellow.* Does *not* give a crystalline precipitate when shaken with tartaric acid solution (*compare* Potassium).	If no metal has been detected, test for free acid or organic substance.

GROUP TESTS FOR ACID RADICALS AND NEUTRAL ORGANIC SUBSTANCES.

NOTE.—In the case of a **Sulphide** or **Carbonate**, insoluble in water, and that has required the addition of acid to effect solution, the acid-radical should have been already detected, as of course it cannot be found in the solution so prepared. For notes on these and other insoluble bodies, see pages 25-29.

Evaporate a small portion of the original solution to dryness and strongly heat the residue.

I. **Charring** and smell of burnt sugar indicates:

Tartrates (neutral or acid, but not sweet, to taste). Confirm with silver mirror test. (*N.B.*—This test does not succeed with tartar emetic.)

Glucose (sweet to taste). Confirm with Trommer's test, ($CuSO_4$ + KOH warmed with the solution suffers reduction).

Sucrose (sweet to taste). Trommer's test does not give reduction. But if the test is applied after the solution has been boiled with dilute acid and then neutralized, reduction of the copper salt takes place.

II. **No charring.** Test solution with litmus, and, if strongly acid, add ammonium hydrate in slight excess, filter from any precipitate that may form, and examine the filtrate as given in *Group A* on next page; but if neutral, alkaline, or faintly acid, proceed to this Group without addition of ammonia.

Group A.

To the original solution or the ammoniacal filtrate (see previous page) add,

BARIUM NITRATE.*

White precipitate	Insoluble in HCl	**Sulphates.**—$Pb(C_2H_3O_2)_2$ to original solution gives *white precipitate.*
	Soluble with effervescence in HCl	**Carbonates.** — Gas evolved, passed into lime-water, renders latter *milky.*
	Soluble without effervescence in HCl	**Oxalates.** — $NH_4OH + CaCl_2$ to original solution gives *white precipitate insoluble in acetic acid.*
		Phosphates. —$NH_4OH + CaCl_2$ to original solution gives *white precipitate soluble in acetic acid.*

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* Barium chloride may be used, as a rule, instead of barium nitrate, except in the case of metals of Group A.

Group B.

If Barium Nitrate has given no precipitate, add to the *original* solution :

SILVER NITRATE.

White or yellowish-white precipitate, insoluble in HNO_3, but soluble in NH_4OH (rather sparingly so in the case of bromides)	**Chloride.**—Precipitate is *insoluble* in excess of original solution. (Original solution shaken with chlorine-water and CS_2: the latter remains *uncoloured.*)
	Bromide.—Precipitate is *insoluble* in excess of original solution. (Original solution shaken with chlorine-water and CS_2: the latter is coloured *orange-red.*)
	Cyanide. — Precipitate is *soluble* in excess of original solution. Confirm by the Prussian blue test (p. 22).
Yellowish-white precipitate, insoluble in both HNO_3 and NH_4OH	**Iodide.** — Original solution shaken with chlorine-water and CS_2: the latter is coloured *violet.*
Black precipitate	**Sulphide.**—Lead acetate to original solution : *black precipitate.*
Brown-black precipitate	**Hydrate.**—Lead acetate to original solution : *white precipitate.*

No precipitate -	**Nitrate.**—Original solution + strong H_2SO_4, cooled, and $FeSO_4$ solution poured in carefully, gives a *black ring* (destroyed by heat). **Acetate.** — Original solution warmed with strong H_2SO_4 gives a smell of vinegar. **Urea.**—Original solution with NaBrO gives evolution of gas (nitrogen); and if a portion of the original solution is concentrated to a few drops, and treated with a little strong HNO_3, a crystalline precipitate $(CO(NH_2)_2.HNO_3)$ is formed.

Note.—Whenever a salt has been detected by this Separation Table, the result should be confirmed by the special tests for metals and acids given on pages 9 24.

PREPARATIONS.

General Notes.

If the substance to be prepared is insoluble in water, the usual method is to precipitate a soluble salt of the metal with a solution of either the sodium, potassium or ammonium salt of the acid. The precipitate so obtained is allowed to stand a few minutes and filtered, the residue being washed, as far as time will allow, with water, the latter being generally warmed, except in one or two preparations (*e.g.*, cupric hydrate) where hot water would alter the body produced.

If, however, the preparation is soluble in water, the usual method is to take a carbonate, oxide, or the metal itself, and treat this with the free acid required until the solution is neutral. The liquid is then evaporated down until a crust of crystals appears; a little hot water is added to dissolve this, and the liquid set aside to crystallize out. It sometimes happens, however, that the crystals are almost as soluble in cold as in hot water (*e.g.*, sodium chloride), and in such a case the best plan is to take the solution almost to dryness, and then drain the crystals from the residual liquid.

The various vessels (flasks, beakers, basins, funnels, etc.) used in making the preparations should be thoroughly cleaned as soon as the operation is completed, being again rinsed with distilled water before another preparation is commenced.

When pouring from one vessel to another, always use a rod, down which the liquid should be allowed to run.

When washing a precipitate in a beaker, etc., by decantation, be careful to avoid getting much of it on the filter until the last washing, otherwise the rapidity of filtration will be decreased.

All solutions used in making a preparation should be quite clear; if this is not the case, filter before you proceed further.

Crystals containing water in the molecule (*e.g.*, zinc sulphate, $ZnSO_4.7H_2O$) should not be heated on the air-bath, as they will lose water and the crystalline character will be destroyed.

As soon as a preparation has been made its reactions and degree of purity should be determined by carefully testing a small portion of the salt.

CHEMICAL PREPARATIONS.

1. **Cupric Sulphate**, $CuSO_4.5H_2O$.

(*a*) From cupric oxide:

$$CuO + H_2SO_4 = CuSO_4 + H_2O.$$

Boil about 50 cc. of diluted sulphuric acid (about 1 in 5) in a beaker, and drop in small portions of cupric oxide from time to time, until the latter just ceases to be dissolved. Then filter the hot solution, and concentrate the blue filtrate until a thin crust begins to form; add about 2 cc. of water to redissolve latter, again boil, and then allow to cool slowly. Drain the crystals, and dry on porous paper.

(*b*) From copper:

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

Place about 4 grms. of copper turnings in a flask, and add about 16 cc. of strong sulphuric acid. Heat cautiously in a fume chamber until the sulphur dioxide almost ceases to be evolved, and dense clouds of sulphuric acid appear ; then allow to cool. When quite cold, add about 30 cc. of water, boil, filter, and concentrate, etc., as in previous preparation.

2. **Cupric Oxide**, CuO.

(*a*) From copper sulphate :

$$\left.\begin{aligned} CuSO_4 + 2KOH \quad &= Cu(OH)_2 + K_2SO_4. \\ Cu(OH)_2 - H_2O \text{ (by boiling)} &= CuO. \end{aligned}\right\}$$

About 5 grms. of copper sulphate are dissolved in water, and the solution precipitated with strong potash solution in slight excess, boiled until the precipitate is quite black, filtered and washed with hot water until free from sulphate (filtrate tested from time to time with barium chloride). The precipitate is dried in the air-bath, or scraped off the paper into a dish, strongly heated, and finally powdered.

(*b*) From copper :

$$\left.\begin{aligned} 3Cu + 8HNO_3 &= 3Cu2NO_3 + 2NO + 4H_2O. \\ 2Cu2NO_3 &= 2CuO + 4NO_2 + O_2. \end{aligned}\right\}$$

About 3 grms. of copper turnings are placed in a beaker, just covered with water, and nitric acid gradually poured on from time to time until the metal is dissolved. The solution so prepared is transferred to a porcelain basin and evaporated to dryness, and strongly heated. The residue of cupric oxide is powdered.

3. **Cupric Hydrate,** $Cu(OH)_2$.

$$CuSO_4 + 2KOH = Cu(OH)_2 + K_2SO_4.$$

A solution of cupric sulphate is prepared by dissolving 5 grms. of the crystallised salt in water, cooled thoroughly, and precipitated with potash solution, avoiding excess of the latter ; this precipitate is filtered through a cloth, washed with *cold water*, pressed, and then air-dried on a porous plate, or on absorbent paper.

4. **Cuprous Oxide**, Cu_2O.

$$\left.\begin{aligned} CuSO_4 + 2KOH &= Cu(OH)_2 + K_2SO_4. \\ 2Cu(OH)_2 - O \text{ (by glucose)} &= Cu_2O + 2H_2O. \end{aligned}\right\}$$

A cold solution of cupric sulphate is made as in the last two preparations, and is treated with potash solution in slight excess. A glucose solution (about 10 per cent.) is then added gradually, the mixture being meanwhile stirred until the blue precipitate dissolves to a dark-blue coloration. The solution is heated to boiling for a few minutes, the precipitate allowed to settle, and then the supernatant liquid is decanted. The red precipitate is well washed with boiling water by decantation, filtered through filter-paper, dried quickly in the air-bath at 100° C. and powdered.

5. **Lead Nitrate**, $Pb2NO_3$.

(*a*) From lead :

$$3Pb + 8HNO_3 = 3Pb2NO_3 + 4H_2O + 2NO.$$

Place about 25 cc. of diluted nitric acid (1 in 3) in a flask, and raise to boiling-point ; whilst boiling drop carefully in from time to time small pieces of granulated lead until the latter ceases to be acted upon. Filter into a beaker, whilst hot, through a filter-paper, and concentrate the filtrate until crystals begin to appear in the liquid ; then add just sufficient hot water to dissolve these, and set the liquid aside to crystallize out. When quite cold, drain the crystals, and press them between dry filter-paper.

(*b*) From lead oxide;

$$PbO + 2HNO_3 = Pb2NO_3 + H_2O.$$

Proceed exactly as in (*a*), but substitute the litharge provided for the lead.

6. **Lead Chloride**, $PbCl_2$.

$$Pb2NO_3 + 2HCl = PbCl_2 + 2HNO_3.$$

About 5 grms. of lead nitrate are dissolved in water containing a few drops of nitric acid, and the solution is precipitated with hydrochloric acid in slight excess. The precipitate is washed once or twice with cold water by decantation, filtered through calico, pressed, and then dried in the water-bath. If desired, the precipitate can be dissolved in the minimum amount of boiling water and crystallized out by cooling.

N.B.—If metallic lead, or litharge, is given for this preparation, the nitrate of lead is made first (see Preparation 5).

7. **Lead Iodide**, PbI_2.

$$Pb(C_2H_3O_2)_2 + 2KI = PbI_2 + 2KC_2H_3O_2.$$

N.B.—Lead nitrate will do equally well for the preparation, but should litharge or metallic lead be given, the nitrate should be prepared first (see Preparation 5).

Dissolve about 5 grms. of the lead acetate provided in warm water containing a few drops of nitric or acetic acid. Add potassium iodide solution (about 10 per cent.) in slight excess, boil, adding water and boiling from time to time until the yellow*

* If the latter is pale in colour (due to basic salt) a few more drops of nitric or acetic acid should be added.

precipitate has dissolved. Then allow the solution to cool slowly and crystallize out. When cold, pour the liquid off the crystals, and wash the latter with cold water, filter and air-dry on paper, or place in a bottle with a little distilled water. The crystals should be in the form of fine golden spangles.

8. **Ammonium Chloride,** NH_4Cl.

$$NH_4OH + HCl = NH_4Cl + H_2O.$$

Place about 20 cc. of strong ammonia solution (·880) in a beaker, dilute with an equal amount of distilled water, and carefully add diluted hydrochloric acid (1 in 2) until the solution is neutral and ceases to smell of ammonia. Boil down until a film begins to form, redissolve this in a few drops of hot water, and set aside to crystallize out. Drain the crystals, and dry them on absorbent paper.

9. **Ammonium Oxalate,** $(NH_4)_2C_2O_4$.

$$2NH_4OH + H_2C_2O_4 = (NH_4)_2C_2O_4 + 2H_2O.$$

Dissolve about 4 grms. of oxalic acid in hot water (about 20 cc.), and carefully add ammonia solution (·880 specific gravity, diluted with an equal amount of water), stirring from time to time until the liquid is neutral or faintly alkaline. Concentrate the solution until crystals begin to appear, then set aside to allow them to form, finally draining them when cold and drying on absorbent paper.

10. **Urea Oxalate,** $2CO(NH_2)_2 \cdot H_2C_2O_4$.

$$2CO(NH_2)_2 + H_2C_2O_4 = 2CO(NH_2)_2 \cdot H_2C_2O_4.$$

Weigh out 2 grms. of urea and 2 grms. of oxalic acid ($H_2C_2O_4 \cdot 2H_2O$), dissolve each separately in the minimum amount of boiling water; mix the solutions, when a mass of crystals of the oxalate will be precipitated. Redissolve these in boiling water, about 3 cc. more than is actually required to effect solution, and allow to recrystallize slowly. When quite cold, drain off, and dry the crystals between filter-paper.

11. **Potassium Nitrate,** KNO_3.

$$\begin{aligned} & K_2CO_3 + 2HNO_3 = {}_2KNO_3 + H_2O + CO_2, \\ \textit{or}\ & KOH + HNO_3 \quad = KNO_3 + H_2O. \end{aligned}$$

Dissolve about 5 grms. of potassium carbonate or hydrate in 20 cc. of water in a beaker. Dilute some nitric acid with an equal volume of water, and pour this carefully into the potash solution, testing with litmus-paper from time to time until neutral or very faintly acid. Boil down until a film begins to form, redissolve this by adding about 2 cc. of water and boiling, then set aside to crystallize out. Drain and dry the crystals as in Preparation 10.

12. **Mercuric Oxide,** HgO.

(*a*) Yellow :

$$HgCl_2 + 2KOH = HgO + 2KCl + H_2O.$$

Dissolve about 3 grms. of mercuric chloride in 70 cc. of hot water, and allow to cool. Dissolve 5 grms. of caustic potash in about 50 cc. of water, and add this solution when cold to the mercuric chloride until the latter becomes alkaline and the precipitate formed is bright yellow. Wash once or twice with cold water by decantation, filter through cloth, press, dry off on water-bath, and finally powder.

(*b*) Red :

$$2Hg2NO_3 = 2HgO + 4NO_2 + O_2.$$

The mercuric nitrate* (5 grms.) is heated in an open basin until all nitrous fumes cease to be evolved. The residue, almost black whilst hot, should become red when cold. If heated for too long a time the oxide itself disappears as mercury and oxygen.

13. **Mercuric Iodide**, HgI_2.

$$HgCl_2 + 2KI = HgI_2 + 2KCl.$$

Make a solution of mercuric chloride in water, as in Preparation 12 (*a*), and divide into two equal portions. Dissolve 5 grms. of potassium iodide in water, and add this solution to one portion of the former until the red precipitate first formed just redissolves again, then add the second half of the mercuric solution, when the red precipitate will be formed once more. Wash with cold water once or twice by decantation, filter through calico, dry in the air-bath, and powder.

14. **Zinc Sulphate**, $ZnSO_4.7H_2O$.

$$Zn + H_2SO_4 = ZnSO_4 + H_2.$$

Place about 5 grms. of zinc in a small flask or beaker, add about 20 cc. of water and a few drops of strong sulphuric acid. Hydrogen will be given off, and the zinc will dissolve. When the action diminishes, add a few more drops of acid, and continue this from time to time, warming the solution, until the metal has almost entirely dissolved. Filter whilst quite hot from the black particles, concentrate the filtrate until a film begins to appear, and set aside to crystallize out. The crystals may be improved by adding about 2 cc. of water, redissolving with the aid of heat, and allowing the solution to recrystallize by slow cooling and spontaneous evaporation.

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* The mercuric nitrate may be prepared from mercury by boiling the latter with nitric acid and 2 or 3 cc. of water until dissolved. Upon cooling this solution the nitrate will crystallize out, or if evaporated to dryness and heated strongly, it gives the red oxide.

N.B.—Zinc oxide or carbonate may be used in place of the metal ; in these cases follow the directions given for magnesium sulphate.

15. **Magnesium Sulphate,** $MgSO_4.7H_2O$.

$$MgCO_3 + H_2SO_4 = MgSO_4 + CO_2 + H_2O.$$

Take about 5 grms. of magnesium carbonate, cover with about 20 cc. of water, and add diluted sulphuric acid (1 to 2) carefully from time to time until the whole has dissolved and the solution is neutral or very faintly acid. Filter if necessary, and concentrate until a film of crystals begins to appear, and then proceed as in the preparation of zinc sulphate (No. 14).

16. **Barium Nitrate,** $Ba2NO_3$.

$$BaCO_3 + 2HNO_3 = Ba2NO_3 + CO_2 + H_2O.$$

In this preparation proceed as in the case of magnesium sulphate, using barium carbonate and nitric acid in the place of magnesium carbonate and sulphuric acid. After filtering the solution, if necessary, concentrate until small crystals appear in the liquid ; then stop heating, and set aside to crystallize out. These crystals may be obtained larger by recrystallization, if about 2 or 3 cc. of water are added and the liquid warmed to redissolve them.

N.B.—Barium oxide or hydrate may be used instead of the carbonate.

Equations :

$$\begin{aligned} & BaO + 2HNO_3 &&= Ba2NO_3 + H_2O, \\ \textit{or}\ & Ba(OH)_2 + 2HNO_3 &&= Ba2NO_3 + 2H_2O. \end{aligned}$$

A strong hot solution of barium chloride treated with strong nitric acid also gives a precipitate of barium nitrate, which can be filtered, dissolved in hot water, and recrystallized.

$$BaCl_2 + 2HNO_3 = Ba2NO_3 + 2HCl.$$

17. **Calcium Sulphate**, $CaSO_4.2H_2O$; or anhydrous, $CaSO_4$.

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$
$$CaCl_2 + H_2SO_4 = CaSO_4 + 2HCl.$$

In this preparation it is best to dissolve the calcium carbonate provided (about 4 grms.) in hydrochloric acid first. The acid should be added carefully until solution just takes place. Sulphuric acid (1 to 2) is then added drop by drop until further precipitation ceases, the precipitate being washed with successive small portions of cold water, and finally dried in the porcelain basin over the Bunsen flame and powdered.

18. **Calcium Phosphate**, $Ca_3P_2O_8$.

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$
$$3CaCl_2 + 2Na_2HPO_4 + 2NaOH = Ca_3P_2O_8 + 6NaCl + 2H_2O.$$

The marble or other form of calcium carbonate provided (about 5 grms.) is dissolved in diluted HCl (1 to 2), and the solution of calcium chloride so prepared is precipitated with a strong solution of sodium phosphate (containing 12 grms. of crystallized phosphate, $Na_2HPO_4.12H_2O$), and a solution of caustic soda (about 10 per cent.) is added until no further precipitation takes place. The mixture is raised to boiling, being well stirred meanwhile to prevent bumping, and boiled for five minutes. This is filtered while hot, the precipitate washed with hot water, dried in the air-bath, or removed from the filter-paper and dried by heating in a porcelain basin. The residue should finally be powdered.

19. Iron Phosphate.

(*a*) **Ferrous Phosphate,** $Fe_3P_2O_8$.

$$3FeSO_4 + 2Na_2HPO_4 + 2NaOH = Fe_3P_2O_8 + 3Na_2SO_4 + 2H_2O.$$

If metallic iron is given, this should be dissolved in dilute hydrochloric acid, and the ferrous chloride so prepared treated like the ferrous sulphate.

$$Fe + 2HCl = FeCl_2 + H_2.$$
$$3FeCl_2 + 2Na_2HPO_4 + 2NaOH = Fe_3P_2O_8 + 6NaCl + 2H_2O.$$

In the case of either ferrous sulphate or chloride the details are the same as in the preparation of calcium phosphate, except that the operation should be conducted as speedily as possible, and recently-boiled distilled water used for washing, etc., to prevent oxidation to ferric phosphate.

(*b*) **Ferric Phosphate,** $FePO_4$.

$$FeCl_3 + Na_2HPO_4 + NaOH = FePO_4 + 3NaCl + H_2O.$$

If *ferric* phosphate is required, proceed as above, but use ferric chloride in place of ferrous chloride.

20. Bismuth Carbonate, $Bi_2O_2CO_3$, or $2Bi_2O_3.Bi_2(CO_3)_3$.

$$\begin{aligned} Bi + 4HNO_3 &= Bi(NO_3)_3 + 2H_2O + NO. \\ 2Bi(NO_3)_3 + 3(NH_4)_2CO_3 &= Bi_2O_2CO_3 + 2CO_2 + 6NH_4NO_3. \end{aligned}$$

The bismuth provided (2 grms.) is dissolved in nitric acid, containing one-third its bulk of water, by the aid of heat. The nitrate of bismuth so prepared is diluted with water and more nitric acid, and this solution is poured carefully into a solution of ammonium carbonate, previously prepared by dissolving 20 grms. of the crystals in water. The precipitate that forms is allowed to settle, the clear upper liquid poured off, and the former washed by decantation, filtered through a piece of calico, dried in the air-bath, and powdered.

21. **Magnesium Carbonate,** $3MgCO_3.Mg(OH)_2$.

$$4MgSO_4 + 4Na_2CO_3 + H_2O = 3MgCO_3.Mg(OH)_2 + 4Na_2SO_4 + CO_2.$$

The sulphate of magnesia (5 grms.) is dissolved in water, and precipitated by a solution of sodium carbonate (6 grms.), the latter being carefully added until further precipitation ceases. The mixture is boiled and filtered hot, the precipitate washed with hot water, dried on the water-bath, and powdered.

22. **Sodium Sulphate,** $Na_2SO_4.10H_2O$.

(*a*) From sodium carbonate :

$$Na_2CO_3 + H_2SO_4 = Na_2SO_4 + CO_2 + H_2O.$$

The crystallized carbonate of soda (10 grms.) is dissolved in 20 cc. of hot water and cooled, and 3 cc. of this solution placed in a test-tube. About 3 cc. of strong sulphuric acid are diluted with four times their bulk of water, and carefully added to the bulk of the soda solution until the latter is just acid to litmus-paper. The remainder of the soda solution is then added drop by drop until the reaction is quite neutral. The liquid, filtered if necessary, is concentrated until a crust begins to appear ; this is dissolved by the addition of a few drops of water and by boiling, the solution being then set aside to crystallize out. When quite cold, the crystals are drained and dried on filter-paper.

(*b*) From sodium chloride :

$$\left.\begin{array}{l} NaCl + H_2SO_4 \quad = NaHSO_4 + HCl \\ NaCl + NaHSO_4 = Na_2SO_4 + HCl \end{array}\right\}$$

The sodium chloride should be covered with a slight excess of diluted sulphuric acid (1 in 2) and strongly heated in the fume chamber until vapour ceases to be evolved. When cold the residue may be dissolved in the minimum amount of boiling water and recrystallised.

23. **Sodium Carbonate,** Na_2CO_3 ; or crystallized, $Na_2CO_3.10H_2O$.

$$\begin{array}{l} CO_2 + NaOH = NaHCO_3. \\ 2NaHCO_3 \quad = Na_2CO_3 + CO_2 + H_2O. \end{array}$$

Place some small pieces of marble in a Wolff's bottle provided with a thistle funnel and a gas-delivery tube, cover with water, and add HCl in small portions at a time down the funnel to secure a steady evolution of CO_2. Pass this gas through a solution of sodium hydrate (5 grms. dissolved in about 15 cc. of water) until the CO_2 is no longer absorbed. Then boil the solution down to dryness, and strongly heat the residue of $NaHCO_3$ for five or ten minutes to convert it to Na_2CO_3. When cool, dissolve in least amount of boiling water and crystallize out, or else powder the dry residue and show up as anhydrous sodium carbonate.

24. **Sodium Hydrate,** NaOH.

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$

Dissolve 10 grms. of sodium carbonate crystals in about 40 cc. of water, and raise the solution to boiling. Stir up about 8 grms. of slaked lime with an equal bulk of water, and pour this into the boiling carbonate solution with constant stirring. Allow the whole to boil for ten minutes, filter whilst hot, and concentrate the filtrate in a porcelain, or, better, a nickel or iron basin, almost to dryness. Sodium hydrate will then separate out as a solid mass, which can be broken up and placed in a corked bottle.

25. **Sodium Chloride**, NaCl.

$$Na_2CO_3 + 2HCl = 2NaCl + CO_2 + H_2O.$$

About 20 grms. of crystallized carbonate of soda are dissolved in hot water (about 20 cc.) in a basin by the aid of heat. Hydrochloric acid (20 cc.) is then carefully added to the solution until the latter is neutral or very faintly acid to litmus. The solution of salt so prepared is evaporated down in the basin almost to dryness, filtered, and the crystals, after being squeezed between filter-paper, are dried in a clean porcelain dish over a small flame.

26. **Calcium Carbonate**, $CaCO_3$.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

Dissolve about 5 grms. of calcium chloride in 30 cc. of water and raise the solution to boiling point. Whilst boiling add a solution of carbonate of soda (15 grms. of crystallised salt) in small portions at a time until precipitation ceases to take place. Boil, with constant stirring, for 5 minutes and filter through filter-paper or calico. Wash once or twice with hot water, dry in the air bath or in a porcelain basin over a low flame and powder.

NOTE.—If marble or limestone is given, this should be dissolved in hydrochloric acid first, and the solution treated as above.

A LIST OF SALTS OF THE PRECEDING ACIDS AND METALS ARRANGED WITH REFERENCE TO THEIR SOLUBILITY IN WATER.

Soluble in Water.

All *sodium*, *potassium* and *ammonium salts*, *glucose*, *sucrose*, *urea*, and the *free acids*.
Acetates and *nitrates*.*
Chlorides,* except *silver*, *lead* and *mercurous*.
Bromides, except *silver*, *lead* and *mercurous*.
Iodides, except *silver*, *lead*, *mercurous*, *mercuric*, *copper*, and *bismuth*.
Sulphates, except *lead* and *barium*, but *silver* and *mercurous* are not very soluble.

Insoluble in Water.

The following salts of metals other than *sodium*, *potassium* and *ammonium* :

Arsenites, *arsenates*, *phosphates*, and *carbonates*,† *metals* in the free state.
Sulphides, except *magnesium*, *calcium* and *barium* (ordinary impure *calcium sulphide* is insoluble).
Hydrates and oxides, except *calcium* and *barium* (*magnesium oxide* is also very sparingly soluble in water).
Cyanides, except *mercuric*, *calcium*, *barium*, and *magnesium*.

---

* The student should remember that antimony chloride and bismuth nitrate and chloride react with water to form white oxy-salts, which require the addition of acid to render them soluble.

† Certain carbonates (*e.g.*, calcium, magnesium, etc.) are soluble in water containing carbon dioxide, but are precipitated on boiling the solution.

Tartrates, except *aluminium*, *tartar emetic* (*antimony-potassium tartrate*), *iron*, *copper*, *magnesium*, and *mercurous* (the last three are very sparingly soluble).

Oxalates, except *iron* and *antimony*, which are slightly soluble.

EQUATIONS.

Various Reactions given in the foregoing Analytical Tables and Preparations.

Silver.

$$\begin{aligned}
\mathrm{AgNO_3 + HCl} &= \mathrm{AgCl + HNO_3}. \\
\mathrm{2AgNO_3 + H_2S} &= \mathrm{Ag_2S + 2HNO_3}. \\
\mathrm{AgNO_3 + KI} &= \mathrm{AgI + KNO_3}. \\
\mathrm{2AgNO_3 + K_2CrO_4} &= \mathrm{Ag_2Cr_2O_4 + 2KNO_3}. \\
\mathrm{3AgNO_3 + Na_2HPO_4} &= \mathrm{Ag_3PO_4 + HNO_3 + 2NaNO_3}.
\end{aligned}$$

Lead.

$$\begin{aligned}
\mathrm{Pb2NO_3 + 2HCl} &= \mathrm{PbCl_2 + 2HNO_3}. \\
\mathrm{3Pb + 8HNO_3} &= \mathrm{3Pb2NO_3 + 2NO + 4H_2O}. \\
\mathrm{Pb(C_2H_3O_2)_2 + H_2S} &= \mathrm{PbS + 2HC_2H_3O_2}. \\
\mathrm{Pb(C_2H_3O_2)_2 + 2KI} &= \mathrm{PbI_2 + 2KC_2H_3O_2}. \\
\mathrm{Pb(C_2H_3O_2)_2 + K_2CrO_4} &= \mathrm{PbCrO_4 + 2KC_2H_3O_2}. \\
\mathrm{Pb(C_2H_3O_2)_2 + H_2SO_4} &= \mathrm{PbSO_4 + 2HC_2H_3O_2}. \\
\mathrm{Pb2NO_3 + 2KOH} &= \mathrm{Pb(OH)_2 + 2KNO_3}.
\end{aligned}$$

Mercurous Salts.

$$\begin{aligned}
\mathrm{Hg_2(NO_3)_2 + 2HCl} &= \mathrm{2HgCl + 2HNO_3}. \\
\mathrm{2HgCl + 2NH_4OH} &= \mathrm{NH_4Cl + NH_2Hg_2Cl + 2H_2O}. \\
\mathrm{Hg_2(NO_3)_2 + H_2S} &= \mathrm{Hg_2S + 2HNO_3}. \\
\mathrm{Hg_2(NO_3)_2 + 2KI} &= \mathrm{Hg_2I_2 + 2KNO_3}. \\
\mathrm{Hg_2Cl_2 + SnCl_2} &= \mathrm{2Hg + SnCl_4}. \\
\mathrm{6HgCl + 8HNO_3} &= \mathrm{3Hg(NO_3)_2 + 3HgCl_2 + 2NO + 4H_2O}.
\end{aligned}$$

Mercuric Salts.

$$\begin{aligned}
\mathrm{3Hg + 8HNO_3} &= \mathrm{3Hg(NO_3)_2 + 2NO + 4H_2O}. \\
\mathrm{2Hg(NO_3)_2} &= \mathrm{2HgO + 4NO_2 + O_2}. \\
\mathrm{HgCl_2 + 2KOH} &= \mathrm{HgO + 2KCl + H_2O}. \\
\mathrm{2HgCl_2 + SnCl_2} &= \mathrm{2HgCl + SnCl_4}. \\
\mathrm{HgCl_2 + 2KI} &= \mathrm{HgI_2 + 2KCl}. \\
\mathrm{HgCl_2 + H_2S} &= \mathrm{HgS + 2HCl}. \\
\mathrm{HgClNH_2 + 2HCl} &= \mathrm{HgCl_2 + NH_4Cl}.
\end{aligned}$$

Bismuth.

$$\begin{aligned}
&Bi + 4HNO_3 &&= Bi3NO_3 + 2H_2O + NO.\\
&2Bi3NO_3 + 3(NH_4)_2CO_3 &&= Bi_2O_2CO_3 + 2CO_2 + 6NH_4NO_3.\\
&BiCl_3 + H_2O &&= BiOCl + 2HCl.\\
&BiCl_3 + 3KOH &&= Bi(OH)_3 + 3KCl.\\
&2BiCl_3 + 3K_2CrO_4 &&= Bi_2(CrO_4)_3 + 6KCl.\\
&BiCl_3 + 3KI &&= BiI_3 + 3KCl.\\
&2Bi(NO_3)_3 + 3H_2S &&= Bi_2S_3 + 6HNO_3.
\end{aligned}$$

Copper.

$$\begin{aligned}
&Cu + 2H_2SO_4 &&= CuSO_4 + SO_2 + 2H_2O.\\
&3Cu + 8HNO_3 &&= 3Cu2NO_3 + 2NO + 4H_2O.\\
&2Cu2NO_3 \text{ (heated strongly)} &&= 2CuO + 4NO_2 + O_2.\\
&CuSO_4 + 2KOH &&= Cu(OH)_2 + K_2SO_4.\\
&Cu(OH)_2 - H_2O &&= CuO.\\
&2CuSO_4 + K_4FeCy_6 &&= Cu_2FeCy_6 + 2K_2SO_4.\\
&CuSO_4 + H_2S &&= CuS + H_2SO_4.
\end{aligned}$$

Antimony.

$$\begin{aligned}
&SbCl_3 + H_2O &&= SbOCl + 2HCl.\\
&2SbCl_3 + 3H_2S &&= Sb_2S_3 + 6HCl.\\
&2SbCl_3 + 6KOH &&= Sb_2O_3 + 6KCl + 3H_2O.
\end{aligned}$$

$$\left.\begin{aligned}
&K(SbO)C_4H_4O_6 + HCl &&= KHC_4H_4O_6 + SbOCl.\\
&SbOCl + 2HCl &&= SbCl_3 + H_2O.
\end{aligned}\right\}$$

Arsenious Acid.

$$\begin{aligned}
&As_4O_6 + 6H_2O &&= 4H_3AsO_3.\\
&H_3AsO_3 + 3AgNO_3 + 3NH_4OH &&= 3NH_4NO_3 + 3H_2O + Ag_3AsO_3.\\
&H_3AsO_3 + CuSO_4 + 2NH_4OH &&= (NH_4)_2SO_4 + CuHAsO_3 + 2H_2O.\\
&2H_3AsO_3 + 3H_2S &&= As_2S_3 + 6H_2O.\\
&H_3AsO_3 + BaCl_2 + 2NH_4OH &&= 2NH_4Cl + BaHAsO_3.
\end{aligned}$$

Arsenic Acid.

$$\begin{aligned}
&As_2O_5 + 3H_2O &&= 2H_3AsO_4.\\
&2H_3AsO_4 + 5H_2S \text{ (after long time)} &&= As_2S_3 + 8H_2O + 2S.\\
&H_3AsO_4 + 3AgNO_3 + 3NH_4OH &&= 3NH_4NO_3 + Ag_3AsO_4 + 3H_2O.\\
&3NH_4OH + MgSO_4 + H_3AsO_4 &&= MgNH_4AsO_4 + (NH_4)_2SO_4\\
& &&\quad + 3H_2O.\\
&3BaCl_2 + 2H_3AsO_4 + 6NH_4OH &&= Ba_32AsO_4 + 6NH_4Cl + 6H_2O.
\end{aligned}$$

Aluminium.

$AlCl_3 + 3NH_4OH = Al(OH)_3 + 3NH_4Cl.$
$AlCl_3 + Na_2HPO_4 = AlPO_4 + 2NaCl + HCl.$
$K_2SO_4 . Al_2(SO_4)_3 + 6NH_4OH = K_2SO_4 + 2Al(OH)_3 + 3(NH_4)_2SO_4.$
$2AlCl_3 + 3(NH_4)_2S + 6H_2O = 2Al(OH)_3 + 6NH_4Cl + 3H_2S.$

Ferric Salts.

$FeCl_3 + 3NH_4OH = Fe(OH)_3 + 3NH_4Cl.$
$2FeCl_3 + 3H_2S = 2FeS + 6HCl + S.$
or $2FeCl_3 + 3(NH_4)_2S = 2FeS + 6NH_4Cl + S.$
$4FeCl_3 + 3K_4FeCy_6 = Fe_4(FeCy_6)_3 + 12KCl.$
$FeCl_3 + 3KCyS = Fe(CyS)_3 + 3KCl.$
$FeCl_3 + Na_2HPO_4 + NaOH = FePO_4 + 3NaCl + H_2O.$
$2FeCl_3 + 3Na_2CO_3 + 3H_2O = 2Fe(OH)_3 + 3CO_2 + 6NaCl.$

Ferrous Salts.

$FeSO_4 + 2NH_4OH = Fe(OH)_2 + (NH_4)_2SO_4.$
$2Fe(OH)_2 + H_2O + O = 2Fe(OH)_3.$
$FeSO_4 + (NH_4)_2S = FeS + (NH_4)_2SO_4.$
$3FeCl_2 + 2K_3FeCy_6 = Fe_3(FeCy_6)_2 + 6KCl.$
$FeCl_2 + K_4FeCy_6 = K_2Fe_2Cy_6 + 2KCl.$
$3FeSO_4 + 2Na_2HPO_4 + 2NaOH = Fe_3(PO_4)_2 + 3Na_2SO_4 + 2H_2O.$

Zinc.

$ZnSO_4 + (NH_4)_2S = ZnS + (NH_4)_2SO_4.$
$2ZnSO_4 + K_4FeCy_6 = Zn_2FeCy_6 + 2K_2SO_4.$
$3ZnSO_4 + 2K_3FeCy_6 = Zn_3(FeCy_6)_2 + 3K_2SO_4.$
$Zn + H_2SO_4 = ZnSO_4 + H_2.$
$ZnCO_3 + H_2SO_4 = ZnSO_4 + H_2O + CO_2.$
$ZnO + H_2SO_4 = ZnSO_4 + H_2O.$

Barium.

$BaCO_3 + 2HNO_3 = Ba(NO_3)_2 + H_2O + CO_2.$
$Ba(NO_3)_2 + (NH_4)_2CO_3 = BaCO_3 + 2NH_4NO_3.$
$Ba(NO_3)_2 + K_2CrO_4 = BaCrO_4 + 2KNO_3.$
$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl.$

Calcium.

$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O.$
$CaCl_2 + (NH_4)_2CO_3 = CaCO_3 + 2NH_4Cl.$
$CaCl_2 + (NH_4)_2C_2O_4 = CaC_2O_4 + 2NH_4Cl.$
$3CaCl_2 + 2Na_2HPO_4 + 2NaOH = Ca_3(PO_4)_2 + 6NaCl.$
$CaCl_2 + H_2SO_4 = CaSO_4 + 2HCl.$

Magnesium.

$4MgSO_4 + 4Na_2CO_3 + H_2O = 3MgCO_3.Mg(OH)_2 + 4Na_2SO_4 + CO_2.$

$MgCO_3 + H_2SO_4 = MgSO_4 + H_2O + CO_2.$

$3MgSO_4 + 2Na_2HPO_4 = Mg_3(PO_4)_2 + 2Na_2SO_4 + H_2SO_4.$

$MgSO_4 + Na_2HPO_4 + NH_4OH = MgNH_4PO_4 + Na_2SO_4 + H_2O.$

Ammonium.

$NH_4Cl + NaOH = NaCl + NH_3 + H_2O.$

$NH_4OH + HCl = NH_4Cl + H_2O.$

$2NH_4OH + H_2C_2O_4 = (NH_4)_2C_2O_4 + 2H_2O.$

$NH_4Cl + H_2C_4H_4O_6 = NH_4HC_4H_4O_6 + HCl.$

Potassium.

$KCl + H_2C_4H_4O_6 = KHC_4H_4O_6 + KCl.$

$2KCl + PtCl_4 = K_2PtCl_6.$

$K_2CO_3 + 2HNO_3 = 2KNO_3 + CO_2 + H_2O.$

$2KI + Cl_2 = 2KCl + I_2$

Sodium.

$NaOH + CO_2 = NaHCO_3.$

$2NaHCO_3 \text{ (heated)} = Na_2CO_3 + CO_2 + H_2O.$

$NaCl + NH_4HCO_3 = NaHCO_3 + NH_4Cl.$

$$\left.\begin{array}{l} NaCl + H_2SO_4 = NaHSO_4 + HCl. \\ NaCl + NaHSO_4 = Na_2SO_4 + HCl \end{array}\right\}$$

Urea.

$2CO(NH_2)_2 + H_2C_2O_4 = 2CO(NH_2)_2 \cdot H_2C_2O_4.$

$CO(NH_2)_2 + 2KOH = K_2CO_3 + 2NH_3.$

$3KBrO + KOH + CO(NH_2)_2 = KHCO_3 + 3KBr + 2H_2O + N_2.$

$CO(NH_2)_2 + 2HNO_2 = 2N_2 + CO_2 + 3H_2O.$

$3CO(NH_2)_2 \text{ (heated)} = C_3N_3H_3O_3 + 3NH_3.$

Sucrose and Glucose.

$C_{12}H_{22}O_{11} + H_2O \text{ (boiling with dilute acid) } = C_6H_{12}O_6 + C_6H_{12}O_6.$

$C_{12}H_{22}O_{11} - 11H_2O \text{ (boiled with strong } H_2SO_4) = 12C.$

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